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ABSTRACT (Maximum 200 words)

The University of Pittsburgh Space Physics Group in collaboration with the ARO modeling team has (1) completed a systematic organization of the shock and plume spectral data and the electron temperature and density measurements obtained during the BowShock I and II rocket flights which have been submitted to the AEDC Data Center, (2) has verified the presence of CO Cameron band emission during the Antares engine burn and for an extended period of time in the post-burn plume, and (3) have adapted 3-D radiation entrapment codes developed by the University of Pittsburgh to study aurora and other atmospheric phenomena that involve significant spatial effects to investigate the VUV and EUV envelope surrounding the re-entry that create an extensive plasma cloud by photoionization.

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BOW SHOCK DATA ANALYSIS

ARO Contract DAAL 03-92-G-0311

1. BACKGROUND

The University of Pittsburgh Space Physics Group was a member of the experimental and analytical teams that designed, constructed and successfully launched the Bow Shock I and II rocket experiments. These studies of hypervelocity phenomena were supported by the Innovative Science and Technology Division of the Strategic Defense Initiative Organization. The analysis and modeling efforts were coordinated by the Army Research Office. The rocket-borne experiments obtained unique optical and Langmuir probe data on upleg and re-entry bow shocks which have required a fundamental reassessment of our understanding of the factors that control the emission of radiation from high Mach number shock waves, the heat loading on surfaces due to the absorption of vacuum ultraviolet [VUV] radiation and the formation of extended plamas and other precursors in front of the vehicle

2. TASK OBJECTIVES.

The Bow Shock I and II experiments have obtained a wealth of in-situ data on hypervelocity phenomena. The objectives of the present task was for the University of Pittsburgh Space Physics Group (1) to complete a systematic organization of the shock and plume spectral data and the electron temperature and density measurements obtained during the BowShock I and II rocket flights, (2) to submit these results to the AEDC Data Center, (3) to identify the unknown molecular band systems observed in the plume spectra from Bow Shock II, (4) to adapt the 3-D radiation entrapment and ion chemistry codes developed by the University of Pittsburgh to study aurora and other atmospheric phenomena that involve significant spatial effects, to investigate the VUV and EUV envelope surrounding the re-entry that create an extensive plasmas cloud by photoionization and (5) to contribute to the preparation of papers for submission to archival journals. This was a collaborative efforts with the ARO modeling team.

3. SUMMARY OF RESULTS

The Bow Shock I and II datasets have been forwarded to the AEDC Data Center where they are available to the user community. A list of the publications that have resulted from the collaborative effects of the Bow Shock team is attached to this report. Additional papers are still in preparation and the work on non-linear plasma effects has just begun.

The striking molecular bands observed by the aft-viewing monochromator and photometers during the Antares burn and during the post-burn plumes of the Antares and Star-27 engines has been positively identified as CO Camaron band system. Figure 1 provides an example of the UV spectra obtained while observed the post-burn plume of the Antares motor.

During the re-entry maneuvers of Bow Shock II the payload was bumped and subsequently developed a pronounced coning motion that severely complicated the task of obtaining spectral data from the aft scanning spectrometer. The instrument was located approximately 1.2 m from the tip and viewed at right angles to the longitudinal axis of the payload and viewed the wake gases flowing from the nosetip. The retrieved spectra were strongly intensity modulated due to the vehicle's motion.It required a considerable effort to deconvolute these data. Figures 2-7 summarize the complex scenario observed during re-entry and show representative spectra at several altitudes during the descent.

The behavior of the OH(A-X) band system is particularly intriguing and is the subject of a continuing investigation

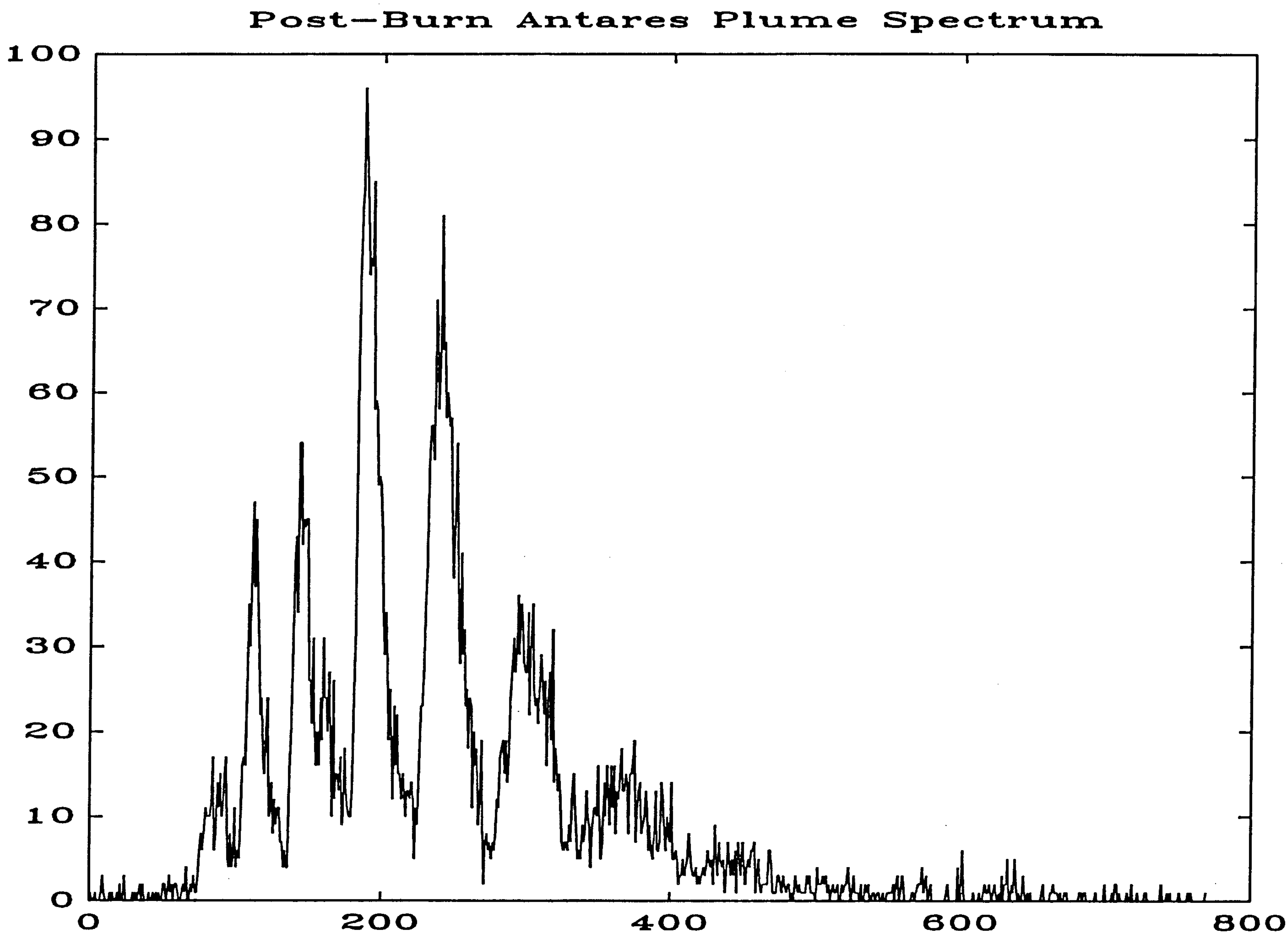
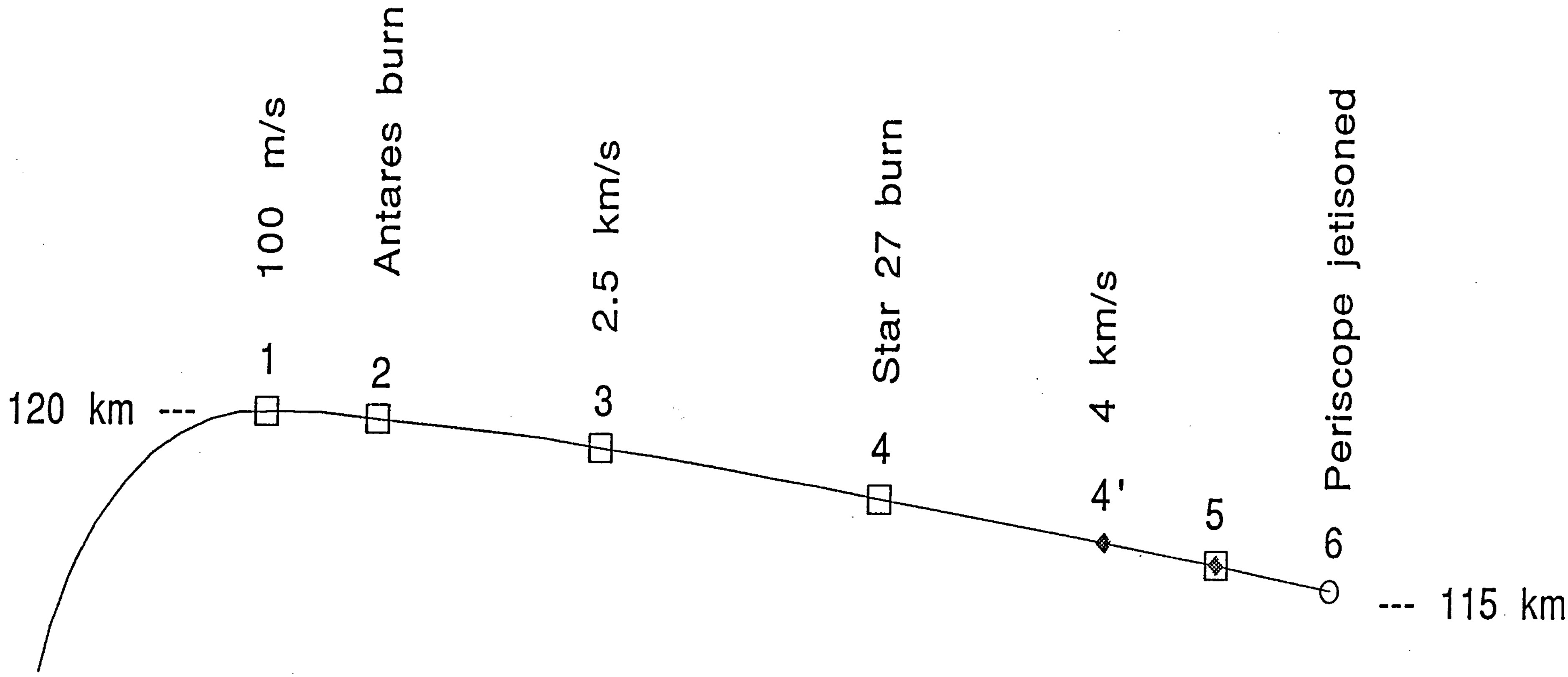


Figure 1. CO Cameron band system observed in the post-burn Antares plume spectrum.



(1) Vehicle at apogee; velocity ~ 100 m/s. No detectable forward or aft emission.

(2) Antares engine burn. Plume measurements begin; no forward emission.

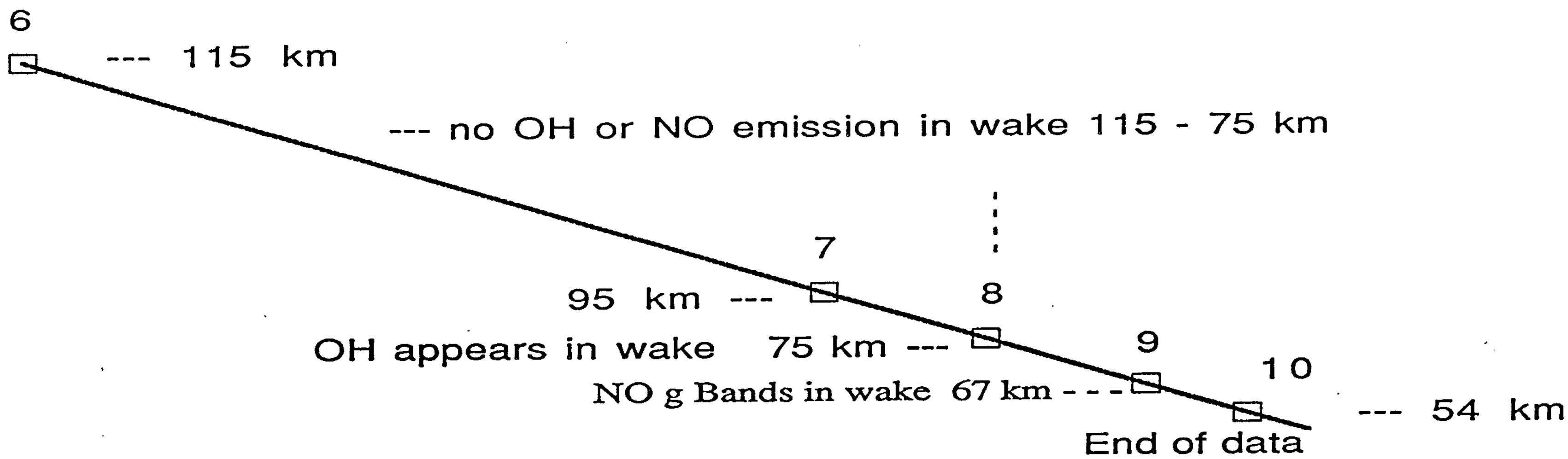
(3) Coast period; vehicle velocity 2.5 km/s. CO(a-X) and OH(A-X) emission persists in the aft direction; no forward emssion.

(4) Star 27 engine burn begins. Plume measurements aft. No forward emission until 6-8 seconds before the end of the engine burn. At that point the vehicle velocity was approximately **4 km/sec** and was at an altitude of 117 km. **OH(A-X) now clearly present in the forward direction. No NO gamma band emission detected in the forward direction until the vehicle was at an altitude of 95 km.** OH(A-X) emission remains nearly constant in intensity from 115 km to 95 km.

(5) OH(A-X) emission observed in the aft direction as the Star 27 plume fades.

(6) Aft periscopes jettisoned approximately 6 seconds after the end of the Star 27 burn. No OH(A-X) emission observed looking sideways at that time.

Figure 2. Sequence of optical events during the re-entry of BowShock II.



(7) Vehicle now at 95 km and moving at 5.1 km/sec. NO gamma band emission detected in the forward (bowshock) direction for the first time and brightening rapidly; OH(A-X) also increasing in intensity in the forward direction.

No OH or NO emission observed by the side-viewing spectrometer from 95 - 75 km.

(8) Vehicle now at 75 km. OH(A-X) emission now detected by the side spectrometer; no NO gamma band emission. The OH(A-X) is <u>not</u> strongly modulated by the coning motion of the vehicle.

(9) At 67 km NO gamma band emission is detected by the side spectrometer at a distance ~1 meter from the nose tip. The NO emission is strongly modulated by the coning motion of the vehicle.

(10) Both the NO and OH emission in the wake continue to brighten by about a factor of five as the vehicle descends to 59 km. The dome has begun to fail and all forward looking instruments fail.

(11) The side-viewing instruments continue to function until the telemetry fails at about 54 km. Very intense NO gamma and OH(A-X) emission is observed sideways with an estimated integrated intensity over the wake volume that may be comparable to the nose tip radiance.

Figure 3. Sequence of optical events during the re-entry of BowShock II.

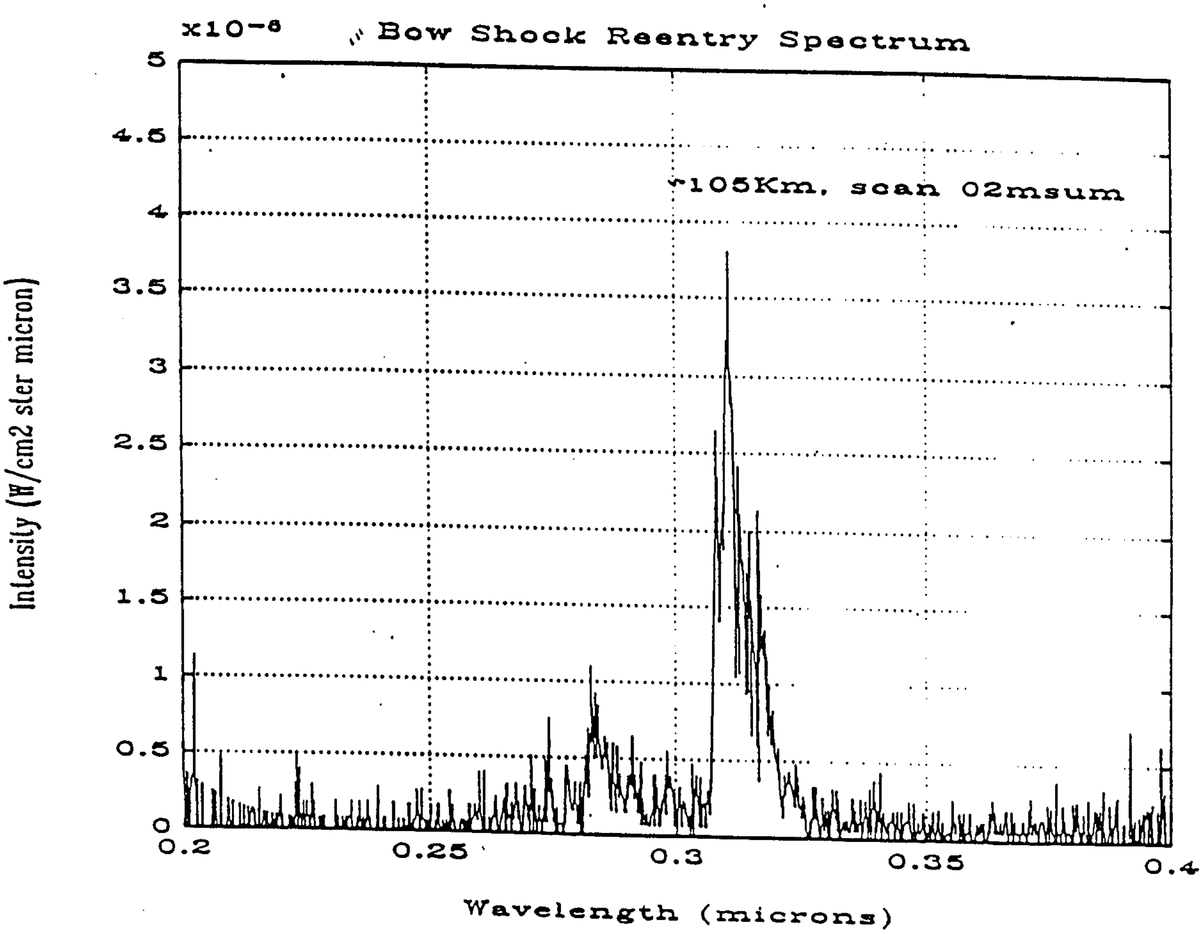


Figure 4. OH(A-X) emission observed in the forward direction after the vehicle had reached a velocity of 4 km/sec. No NO gamma band emission was observed at this time.

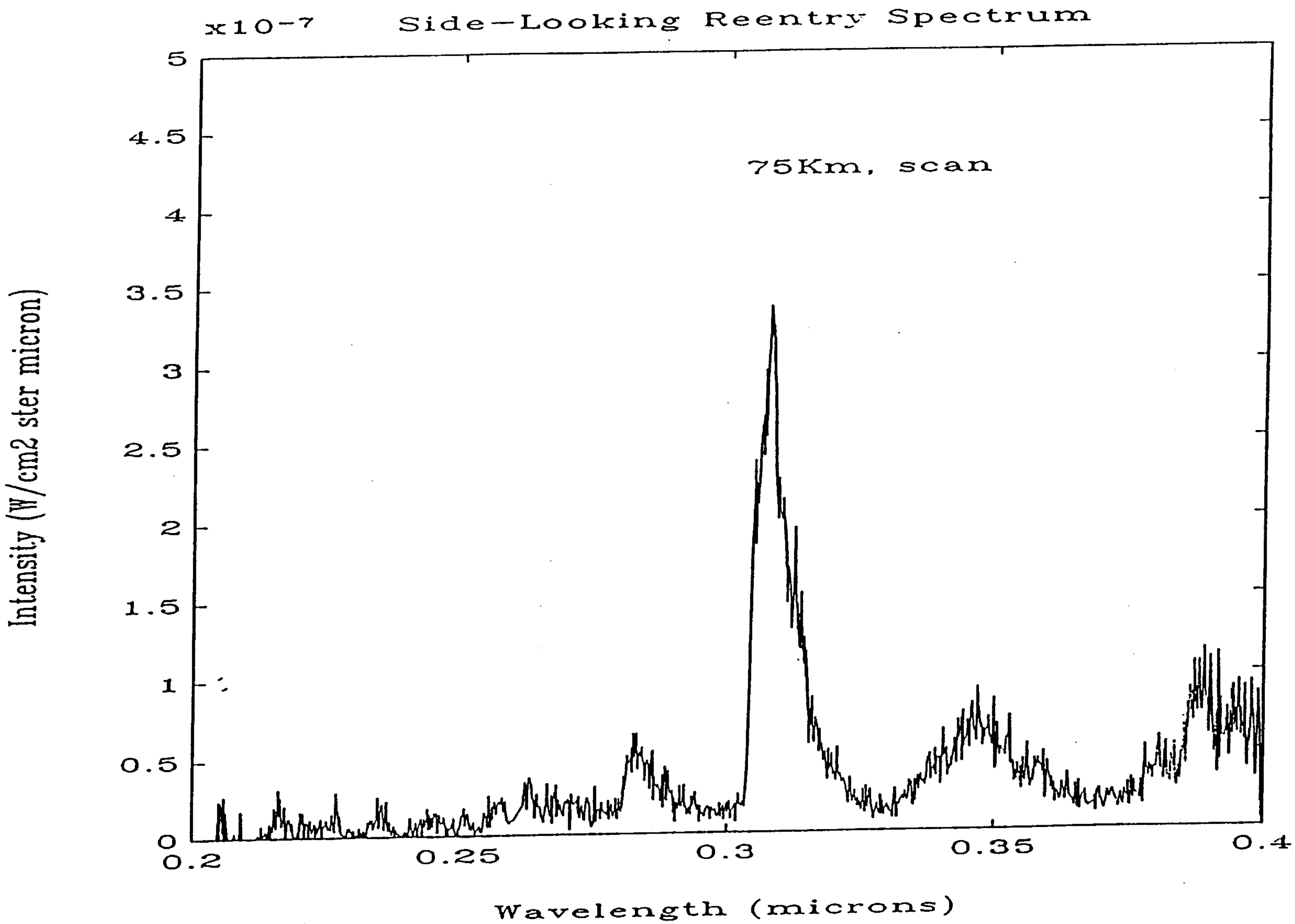


Figure 5. The ultraviolet spectrum observed by the side-viewing scanning monochromator during the final stages of re-entry.

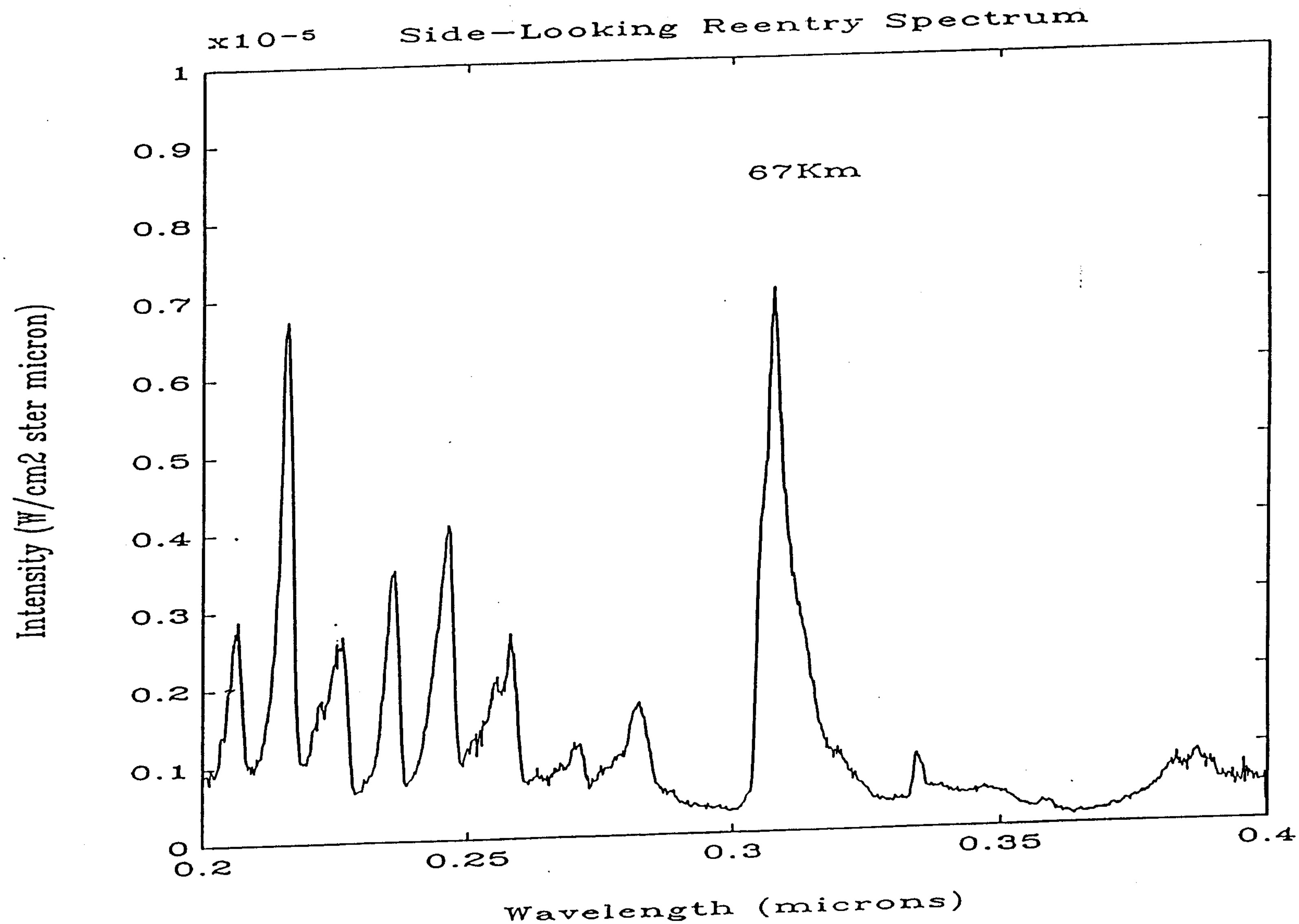


Figure 6. The ultraviolet spectrum observed by the side-viewing scanning monochromator during the final stages of re-entry.

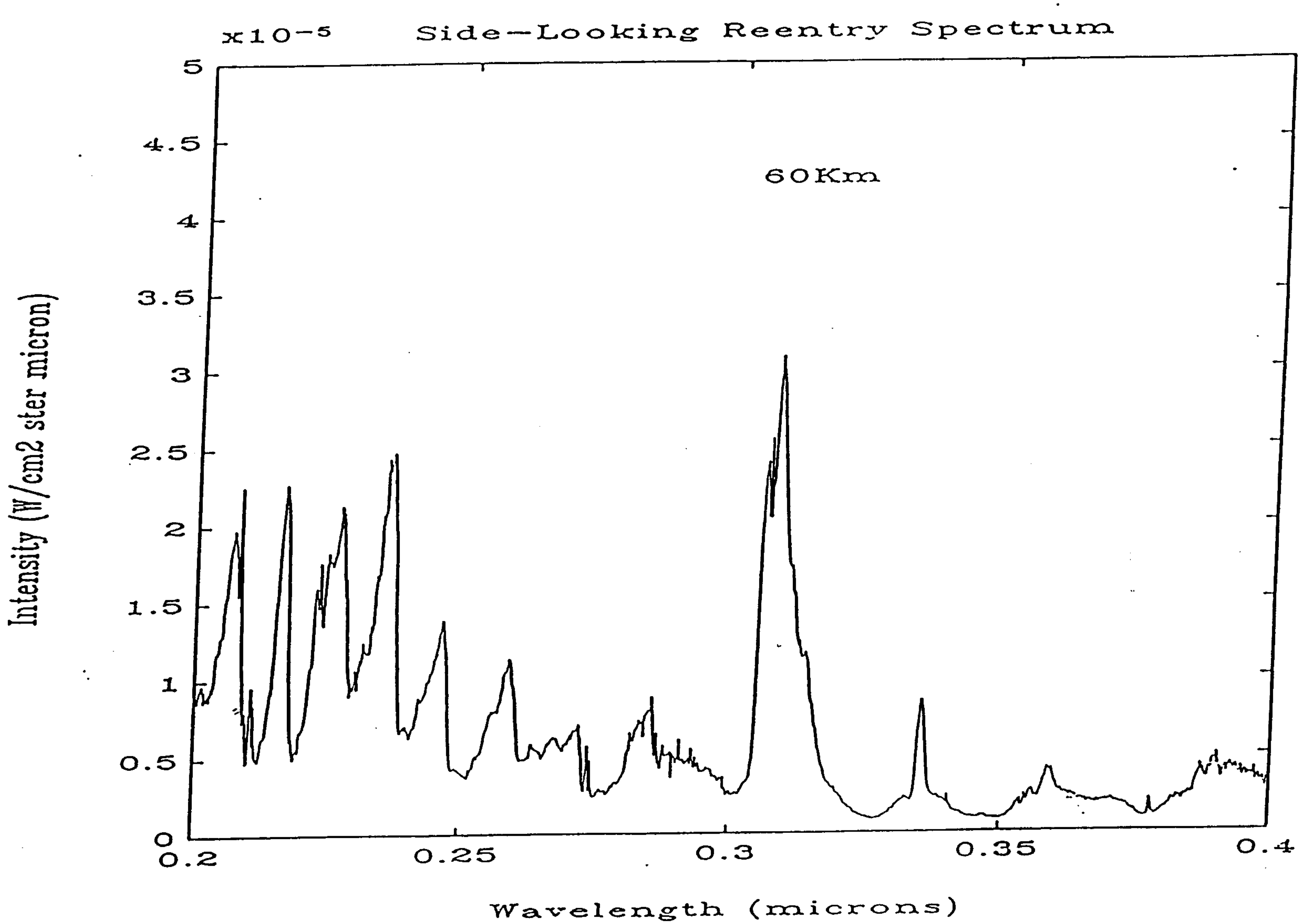


Figure 7. The ultraviolet spectrum observed by the side-viewing scanning monochromator during the final stages of re-entry.

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